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FINAL REPORT

SECURES™ FEASIBILITY STUDY
18 November 1994

Sponsor:
Advanced Research Projects Agency
Maritime Systems Technology Office
ARPA Order Number B348/00
Issued by ARPA Under Contract MDA 972-94-C-0030

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1.0 INTRODUCTION

The purpose of this effort was to determine the feasibility of the SECURES™ (System for the Effective Control of URban Environment Security) system concept as a reliable and practical means to instantly notify police of gunshot locations in urban environments. This feasibility study involved the acquisition of gunshot and background noise acoustic data, analysis of this data to establish methods of identifying gunshots from the background noises, and an investigation into hardware designs for implementation of these methods into a reliable and economical system. This effort also involved breadboarding and testing critical portions of the electronic circuitry and developing a physical model of the pole unit enclosure. Some of the work presented in this report were supported by internal research and development funding provided by Alliant and some results are considered company proprietary. These include: (1) overall SECURES™ system concept; (2) formulation of the gunshot discrimination algorithm; (3 analog pulse detection circuit design; (4) pole unit digital electronics design concept; and (5) design and model construction of the pole unit enclosure.

The SECURES™ System Concept is shown in Figure 1.0-1. This illustrates a map of a 30 square block region of a city and indicates the locations of gunshot detection units (pole units) which are capable of acoustically identifying gunshots and transmitting this finding to the police dispatcher. The detectors are spaced at intervals of approximately one block and are mounted on utility poles or building structures as indicated in Figure 1.0-2. As can be seen from this figure, the pole units are to be small (3"x3"x4") battery powered units that include the acoustic sensing element, gunshot identification electronics, and RF transmitter. The key system performance requirements are:

- Reliable identification of gunshots
- Very low false alarm rates
- Low cost, easy to install, operate, and maintain
- Long life operation in outdoor environments

Decisions regarding further development of the SECURES™ concept, for both military and non-governmental purposes, will be made based on the results of this study. The following sections describe the work performed and results obtained in the areas of: (1) data acquisition and analysis; (2) gunshot identification method and its performance; and (3) the main features of the system hardware development.

2.0 DATA ACQUISITION

As part of the SECURES™ program, Alliant has acquired an extensive database of acoustic signatures from firearms, firecrackers, and environmental background noises relevant to the urban environment. The firearms included pistols, rifles and shotguns selected by the D.C. Police and the FBI to cover the range of weapons most often encountered on the city streets. With the support of the D.C. Police, FBI, U.S. Marines, and the U.S. Army, acoustic data was collected at Ft. Meade, the D.C. Blue Plains Test Range, the U.S. Marine Combat Base, and the U.S. Army Aberdeen Proving Grounds. These tests included firing selected weapons and firecrackers in open field environments as well as among building structures. In addition, Alliant acquired a database of common background noises against which the SECURES™ system must reliably identify gunshots with a very low false alarm rate.

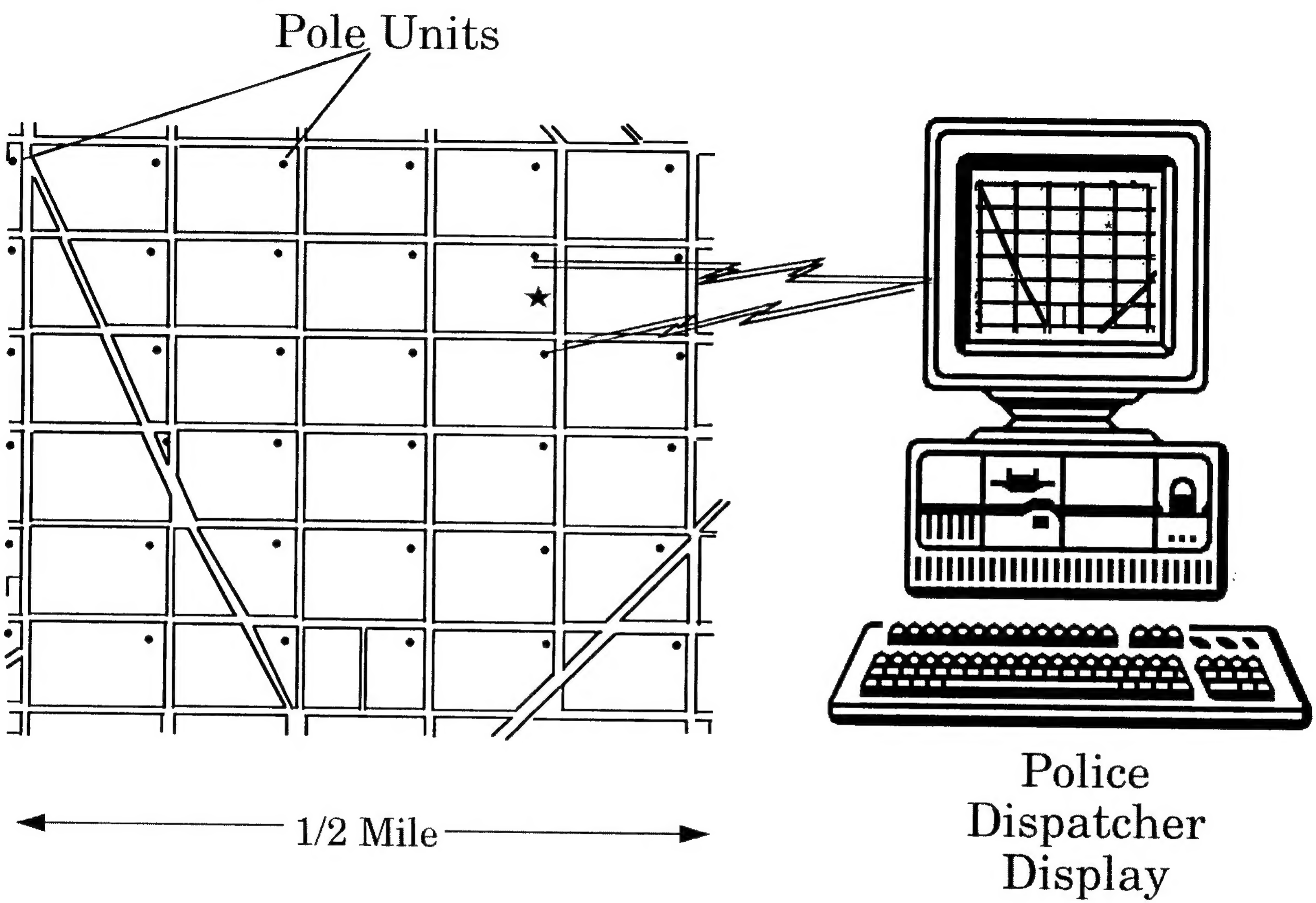


Figure 1.0-1: SECURES™ System Concept

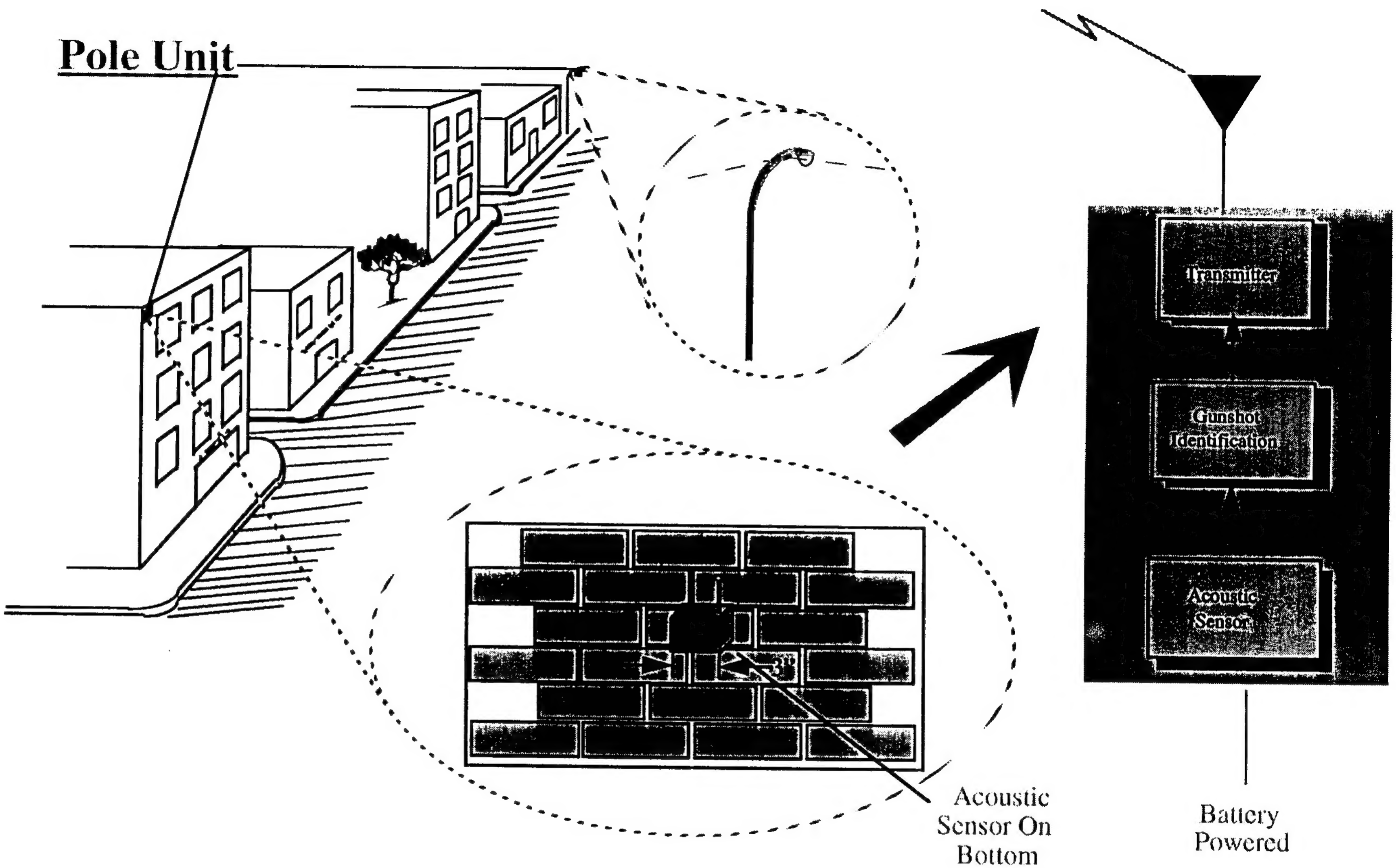


Figure 1.0-2: Pole Unit

2.1 Ft. Meade Test Range

Tests were performed at the Ft. Meade Test Range (open field) primarily for the purposes of characterizing gunshot acoustic waveforms without the interference of reverberations. Data was recorded using B&K microphones and a Baker BE 256 digital data acquisition system (having high bandwidth (0 to > 50kHz) and high dynamic range (>90 dB). Calibrated acoustic sources were used to calibrate absolute sound levels in the recordings. At Ft. Meade, data was recorded from multiple shots from the weapons listed below.

Weapon	# Firings	Weapon	# Firings
Glock 17 (9mm)	16	Rifle (7.62mm)	17
Shotgun (12 Gauge)	17	M-16A1 (5.56mm)	15
M-1911A1 (45ACP)	15	Blank Pistol (.22 Cal)	10
Revolver (.38 Special)	16	Firecrackers (Small, Medium & Large)	20
Uzi SMG (9mm)	17		
		Total	**143**

The majority of shots were recorded at ranges of 25, 75 and 125 meters, and at azimuths of 0, 30, 150 and 180 degrees (although some tests were performed at closer ranges and other azimuths). The configuration for the above tests is shown in Figure 2.1-1 and indicates that data was simultaneously recorded at three different ranges for each shot fired.

2.2 Environmental Noise

Ft. Meade data analysis revealed that frequencies above 20kHz had a negligible contribution to the gunshot waveform which allowed Alliant to put together portable, battery-powered, digital data recording instrumentation. This provided the flexibility necessary to record environmental background noises throughout the city. The instrumentation included a 16 bit DAT recorder with a 44.2kHz sampling rate, a B&K sound level meter/microphone, and a calibration source. A preliminary database of environmental noises was recorded and included those listed below with the number of events or minutes indicated.

Noise	# Minutes	Noise	# Events
Loud City Traffic (15 feet from road)	40 min.	Hammer Strike	10
		Horn Blasts	6
High Wind Gusts	15 min.	Banging Metal Objects	10
Car Engine Revs	2 min.	Hood & Door Slams	6
Air Wrench	5 min.	Firecrackers	10
Loud Voices	2 min.	Balloon Pops	10
		Car Backfire	8

2.3 Blue Plains Test Range

Data was recorded at the D.C. Police Blue Plains Test Range to provide a preliminary finding on the effect reverberant environments have on corrupting gunshot acoustic signatures and what problem this presents in identifying gunshots from other noise sources. This test range environment contained embankments, small buildings, and open-roofed structures as can be seen in Figure 2.3-1. The police fired 9mm Glock pistols from a variety of locations within this range which thereby provided a variety of multipath situations for the data recording. In addition 30 shots were fired from a blank .22 by Alliant and recorded at a variety of locations in and outside the test range area.

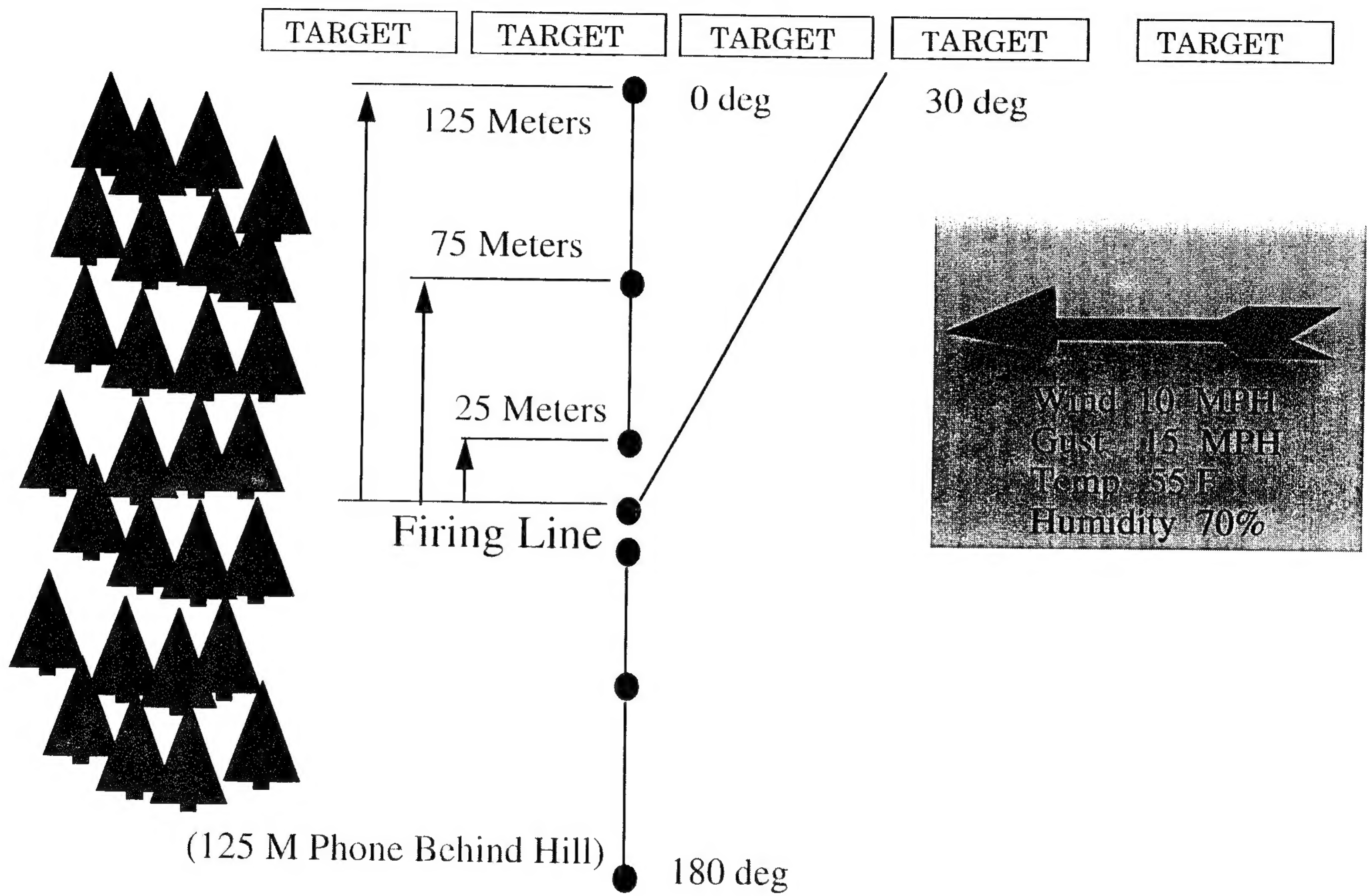


Figure 2.1-1: Test #2 Actual Range Layout

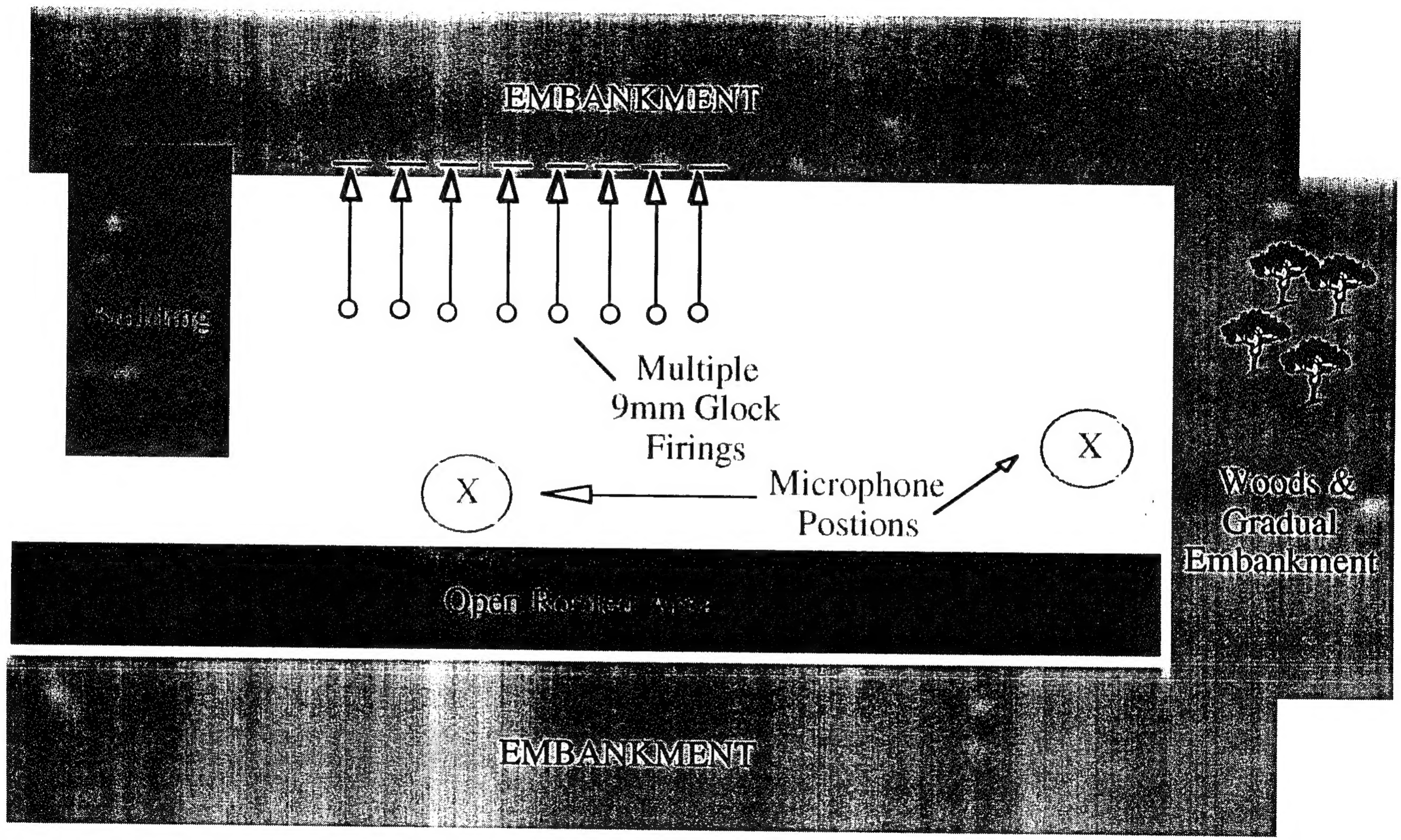


Figure 2.3-1: Blue Plains Test Range

2.4 Marine Combat Base Tests

Since the SECURES™ system is targeting identification of gunshots in urban environments, it was critical to obtain a large database of gunshot acoustic data among building complexes. This would allow for a better understanding of the multipath interference to be expected for different firing locations and directions among structures as a function of the acoustic sensor placement. This would allow a realistic determination of the gunshot identification algorithm requirements. With the cooperation of the FBI and the U.S. Marines, arrangements were made to perform the necessary tests at the Marine Combat Base located in Quantico, VA. This base is used by the Marines for door to door combat training and consists of a complex of one, two, and three-story cinder block buildings to represent a school, bank, apartment buildings, office building, hotel, townhouses and other buildings in a small town setting. The following weapons were fired multiple times during these tests as is listed below:

Weapon	# Firings
Pistol (.22 Caliber)	40
Glock 17 (9mm)	40
Revolver (.38 Special)	40
Revolver (.45 Caliber)	40
M-16 (.223 Caliber)	40
Shotgun (Short Barrel)	40
1" Firecracker	50
TOTAL	290

The weapons were fired from Sites A, B, and C within the Combat Base in the directions indicated on the maps shown in Figures 2.4-1, 2.4-2, and 2.4-3. The firing locations, directions, and microphone positions shown include:

Firing Location & Direction	Microphone Locations
A1, A2, A3, and A4 A1L and A3L for M-16 Only	P1, P2, P3, P4, and P5
B6 and B7 B6L and B7L for M-16 Only	P4, P5, P6, and P7
C8 and C9 C8L and C9L for M-16 Only	P8, P9, P10, and P11

This variety of shot locations and microphone positions provided data for situations ranging from a relatively direct line of sight between buildings to cases in which the acoustic path was directly blocked by buildings, and a case in which the gun was fired in a narrow alley way (B6). Typical situations as well as the most difficult situations anticipated in urban environments are well represented in this data set. Thus analysis of these data should provide realistic estimates of expected detection and false alarm statistics.

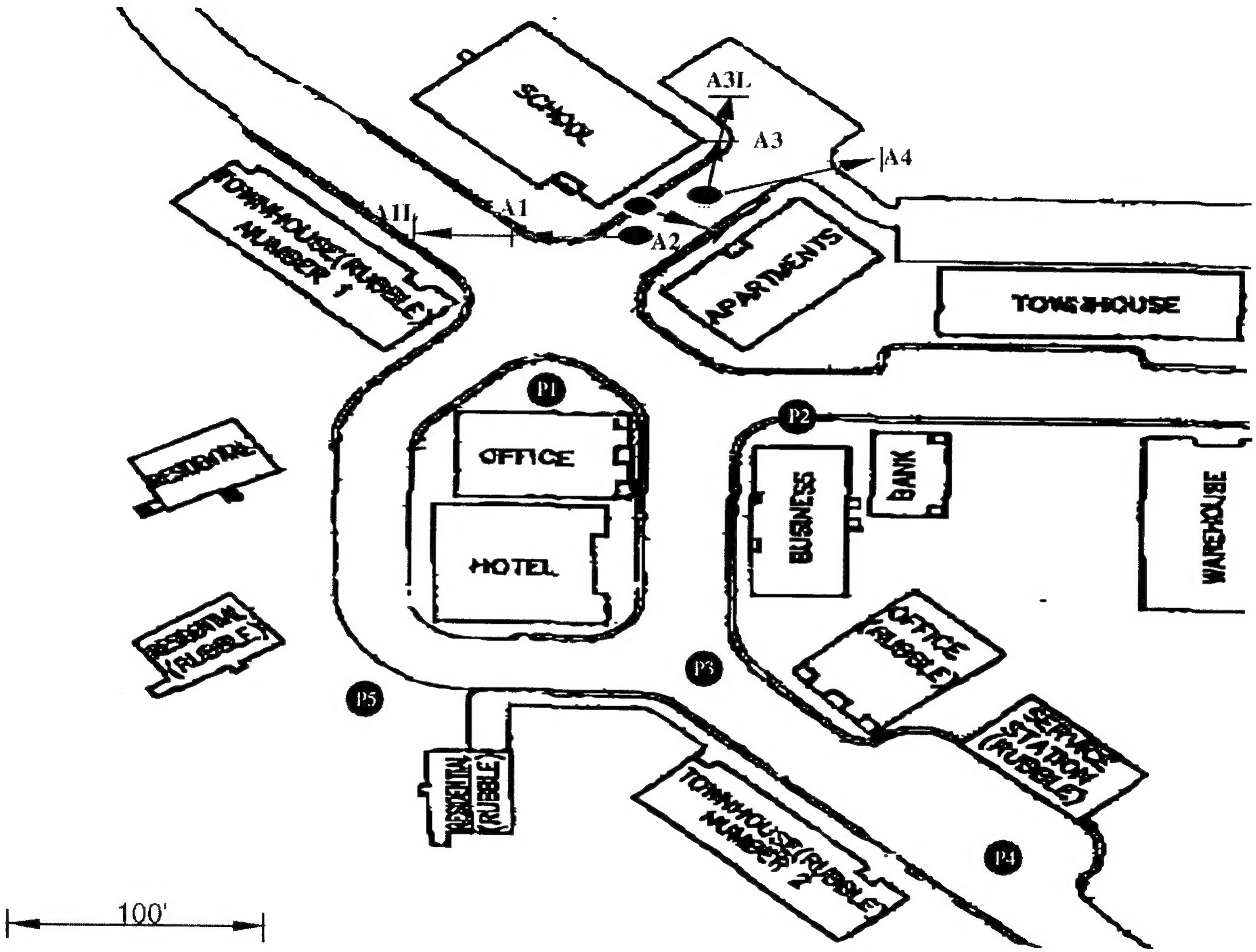


Figure 2.4-1: Site A:
Firing Locations, Target Locations & Microphone Locations

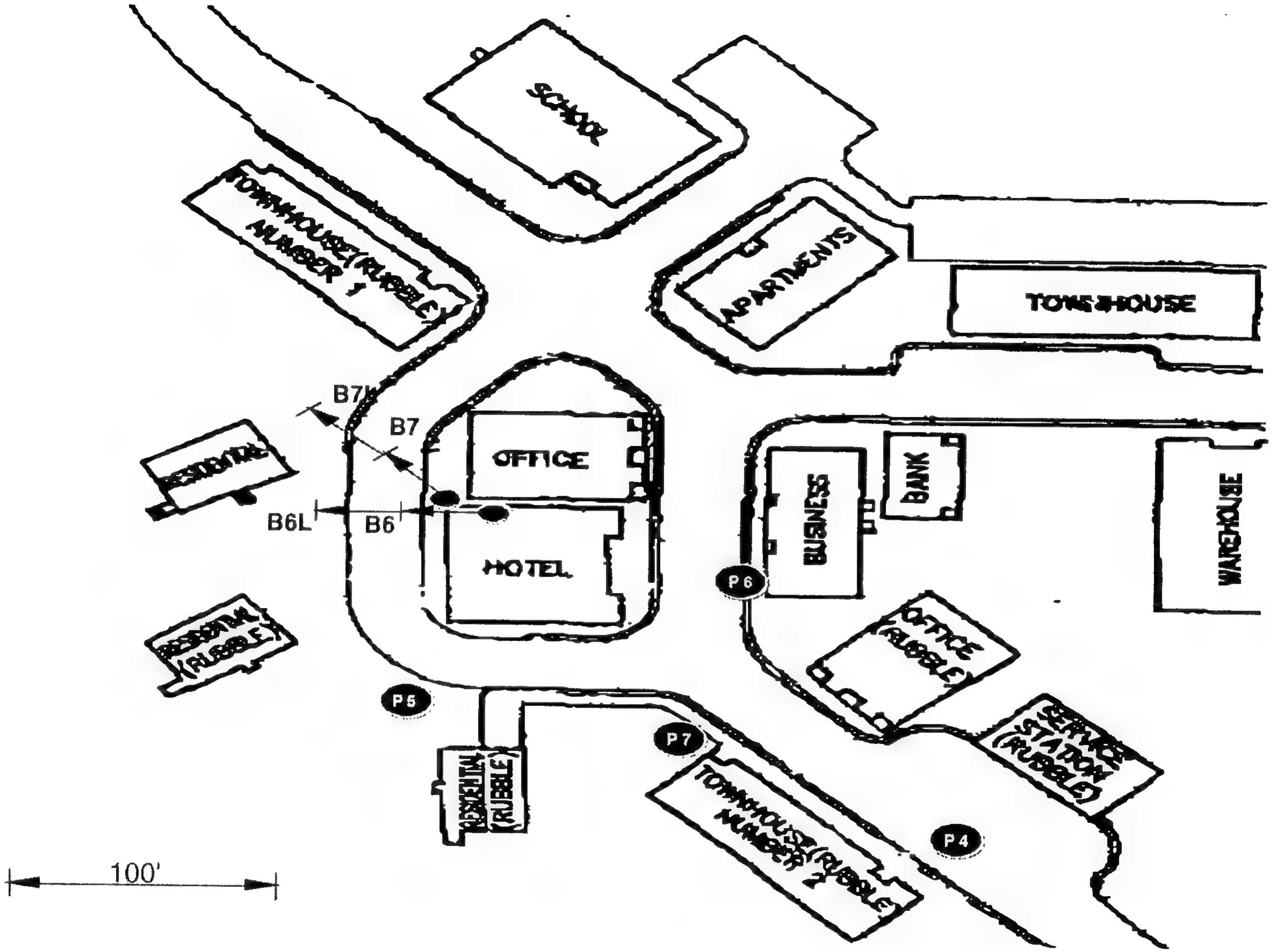


Figure 2.4-2: Site B:
Firing Locations, Target Locations & Microphone Locations

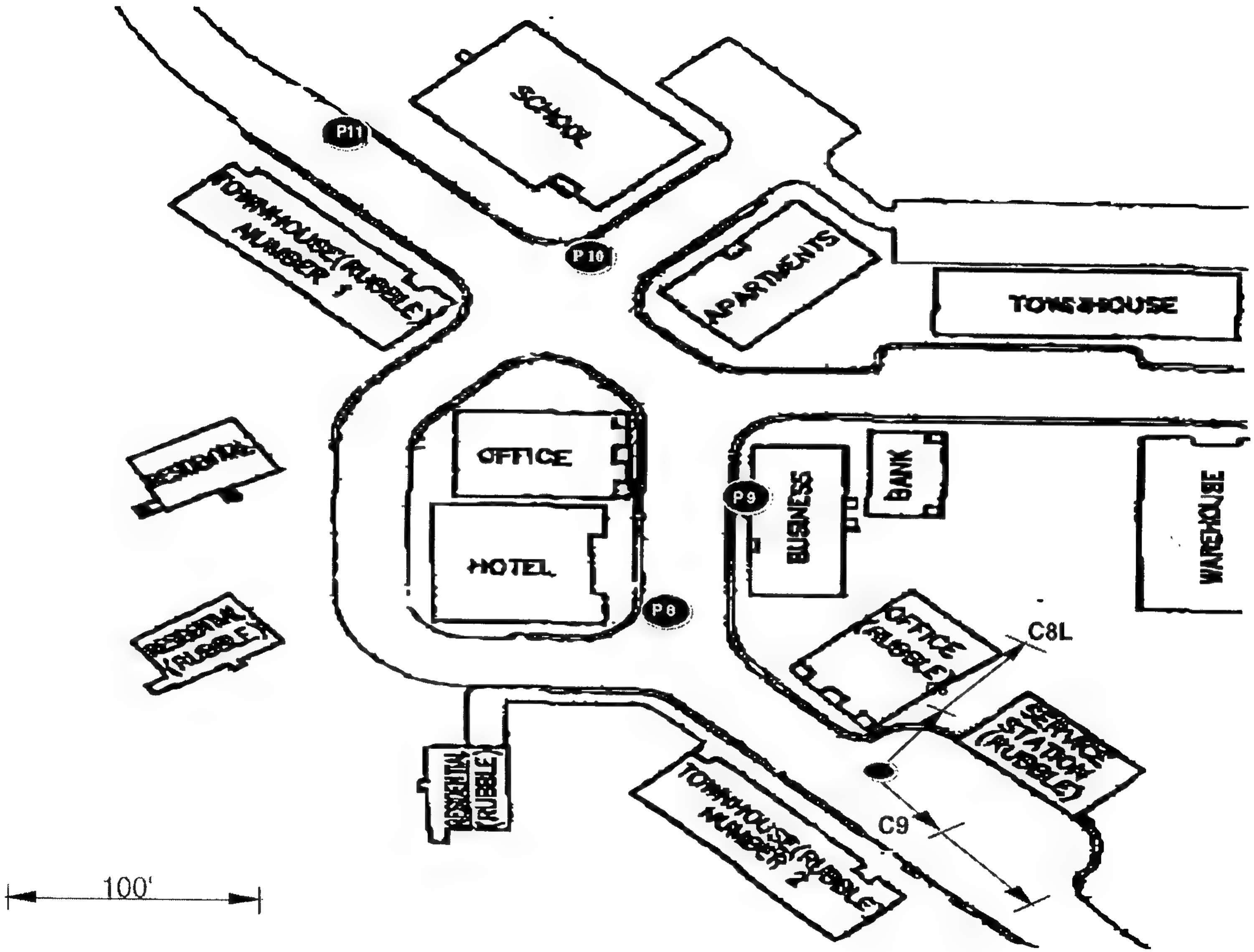


Figure 2.4-3: Site C:
Firing Locations, Target Locations & Microphone Locations

2.5 ARL - Aberdeen

Additional gunshot acoustic data was recorded by Alliant as part of ARL's sniper detection and localization field tests conducted at the Aberdeen Proving Grounds. These data provided useful additional data on the characteristics of the bullet shock wave for the SECURES™ detection algorithm, as well providing data to help us evaluate applications of the SECURES™ system concept for sniper detection in open and city environments. Figure 2.5-1 shows the weapons fired, their locations relative to the acoustic sensor and the directions fired for the data recorded by Alliant.

3.0 CURRENT GUNSHOT IDENTIFICATION METHOD

Based on the analysis of the data acquired at Ft. Meade, acoustic waveform characteristics of the various weapons fired were obtained as a function of range and azimuth. With the analysis of the recorded environmental noise data, those characteristics which best distinguished gunshots from environmental noise were identified. Preliminary analog and digital detection and classification algorithms were then developed for testing on the gunshot data recorded in reverberant environments (i.e., data from Blue Plains and the Marine Combat Village), and their performance evaluated.

3.1 Acoustic Characteristics of Gunshots

The acoustic waves generated by the firing of a gun primarily consist of the muzzle blast waveform, originating from the gas exiting the barrel, and the shock pulse waveform (N-wave) generated when the projectile travels at a supersonic velocity. These characteristics are illustrated in Figure 3.1-1. The shock pulse illustrated results from the shock wave cone passing over the microphone at the speed of sound. In this case a local reflection is also present and appears adjacent to the first pulse. Following the shock wave is the muzzle blast waveform which is always observed from gunfire. Note that the muzzle blast waveform propagating in the rear direction has significantly different characteristics. In an environment in which reflections are present, it is possible that the observed waveform is some combination of the forward muzzle blast, rear muzzle blast, and N-wave waveforms. Figure 3.1-2 illustrates the relative magnitudes of these waveforms. Although the N-wave is much larger it is not as likely to be observed in city environments because most pistols fire subsonic projectiles and the shock wave cone is observed in limited angular regions.

Figures 3.1-3 to 3.1-6 show sample muzzle blast waveforms from a variety of weapons and their variation with propagation distance. There appears to be weapon barrel length dependency presenting the possibility of classifying weapons by their waveform; however this has not been validated. Figure 3.1-7 shows waveforms of different background noise sources and for a Glock pistol. Note how the short pulse nature of the gunshots compare with the other noise sources.

Analysis shows that pulse rise time, pulse duration, and pulse amplitude are very important gunshot discriminators. This is illustrated in Figure 3.1-8. Pulse duration appears to be effective at discriminating gunshots from the vast majority of longer duration background noises as well from the shorter duration pulses of 1" firecrackers when these events happen to meet the rise time and amplitude criteria of gunshots. A comparison of a Glock waveform and that of a 1" firecracker is shown in Figure 3.1-9.

3.2 Affects of Reverberant Environments

Even in the presence of multipaths these properties are still very effective discriminators. This is because the first arrival is either strong and stands out from the later arrivals or has a delay between

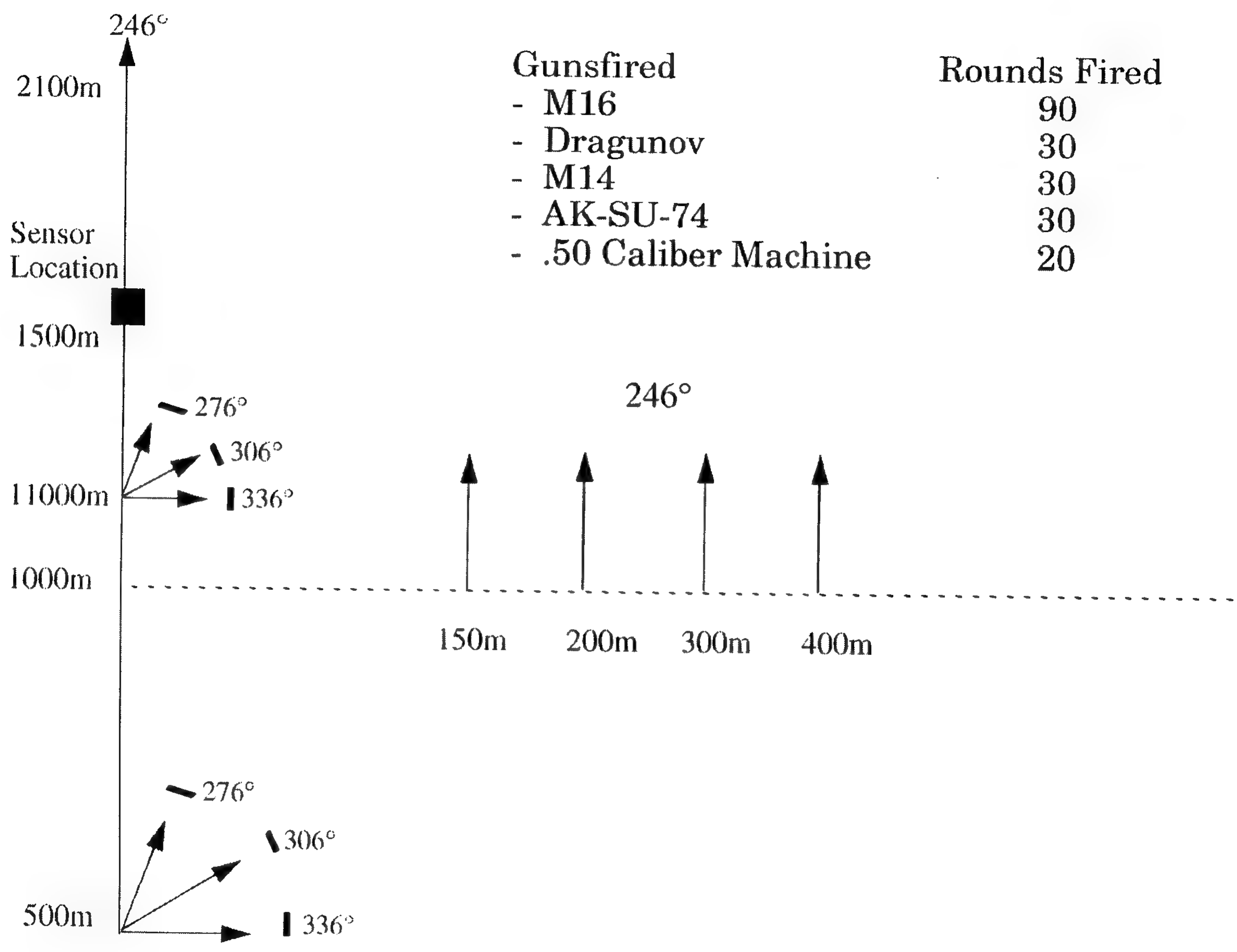


Figure 2.5-1: ARL - Aberdeen

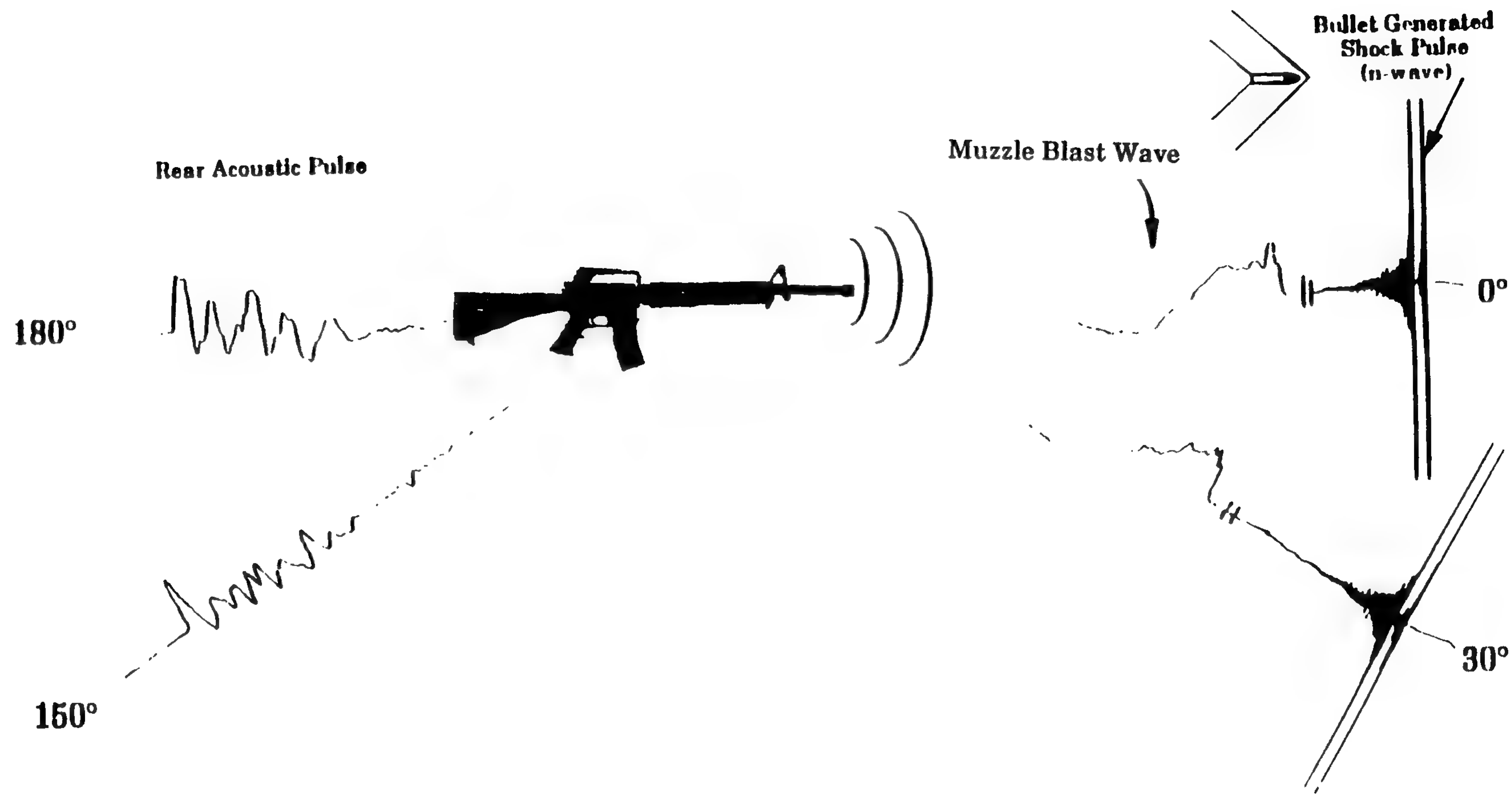


Figure 3.1-1: Gunshot Acoustic Characteristics

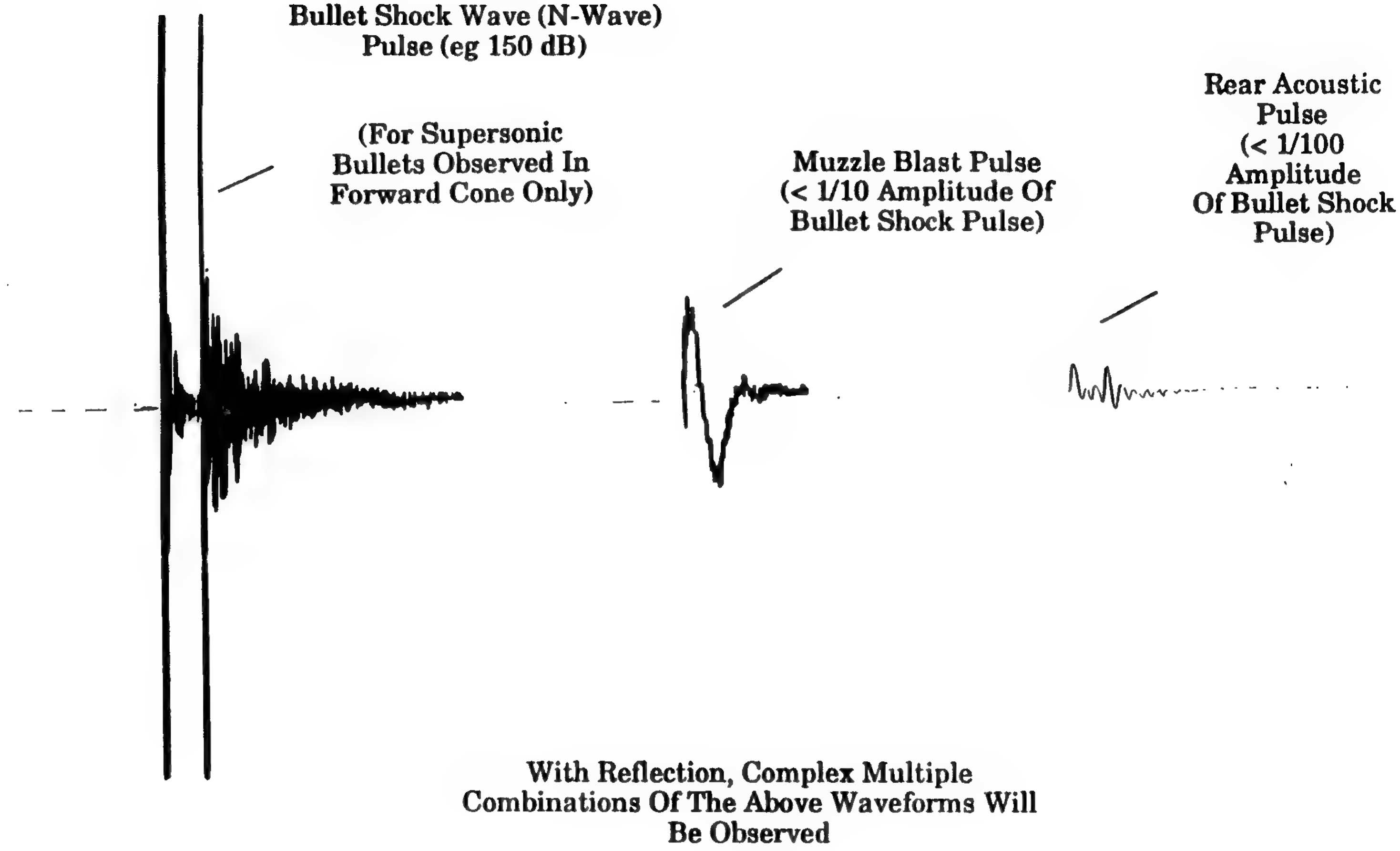


Figure 3.1-2: Gunshot Waveform Components

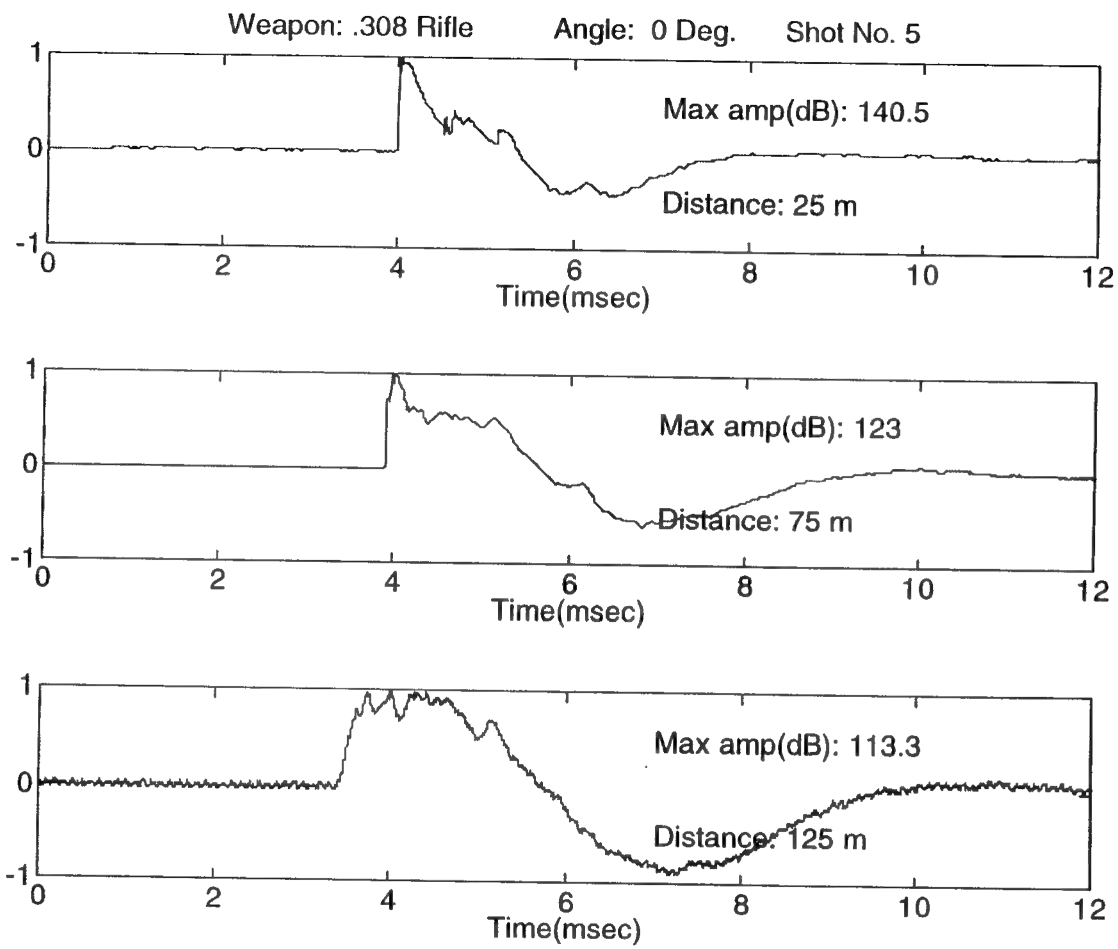


Figure 3.1-3: Waveforms vs. Distance 0°

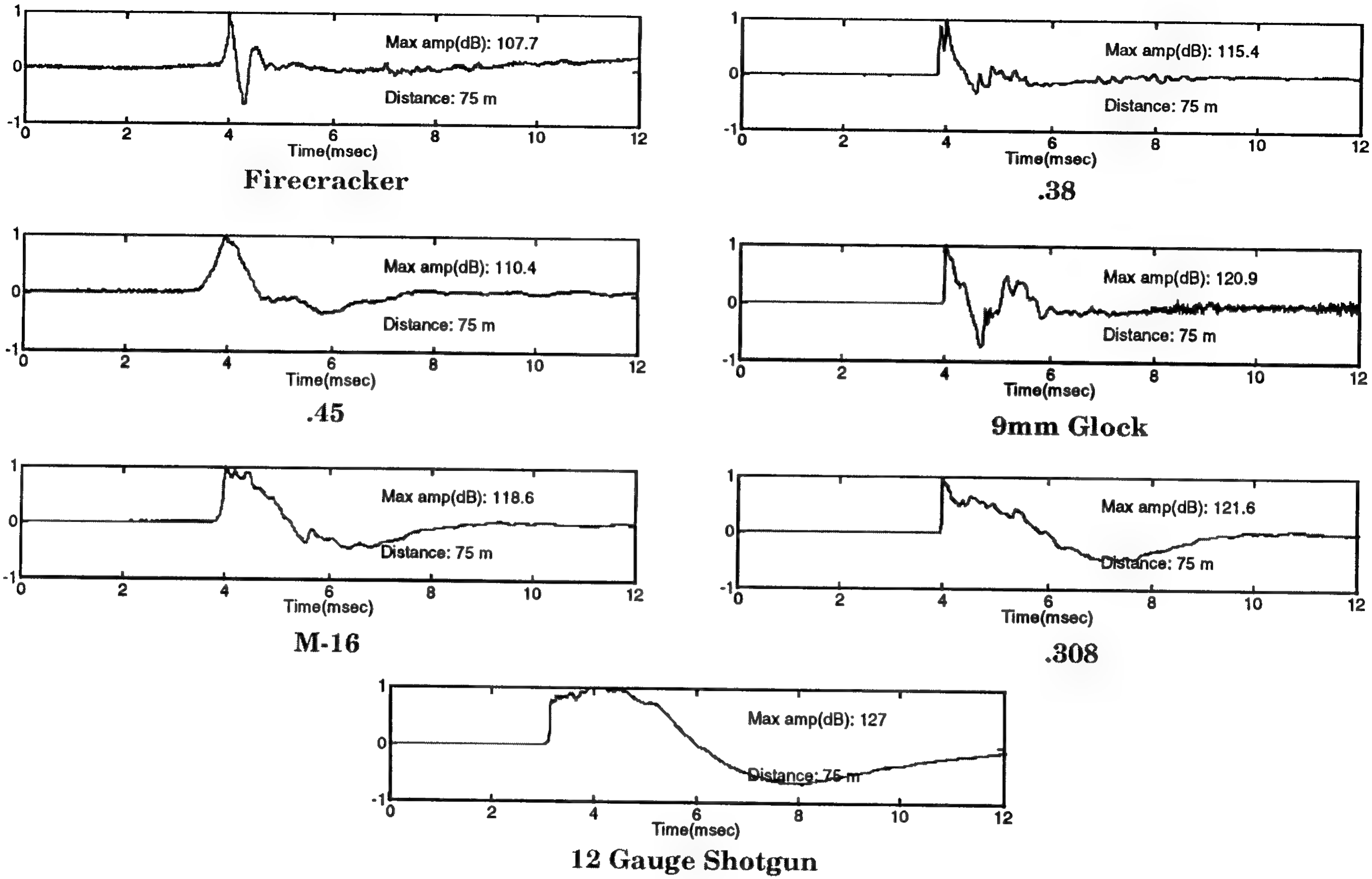


Figure 3.1-4: Acoustic Shock Waveforms Forward Direction

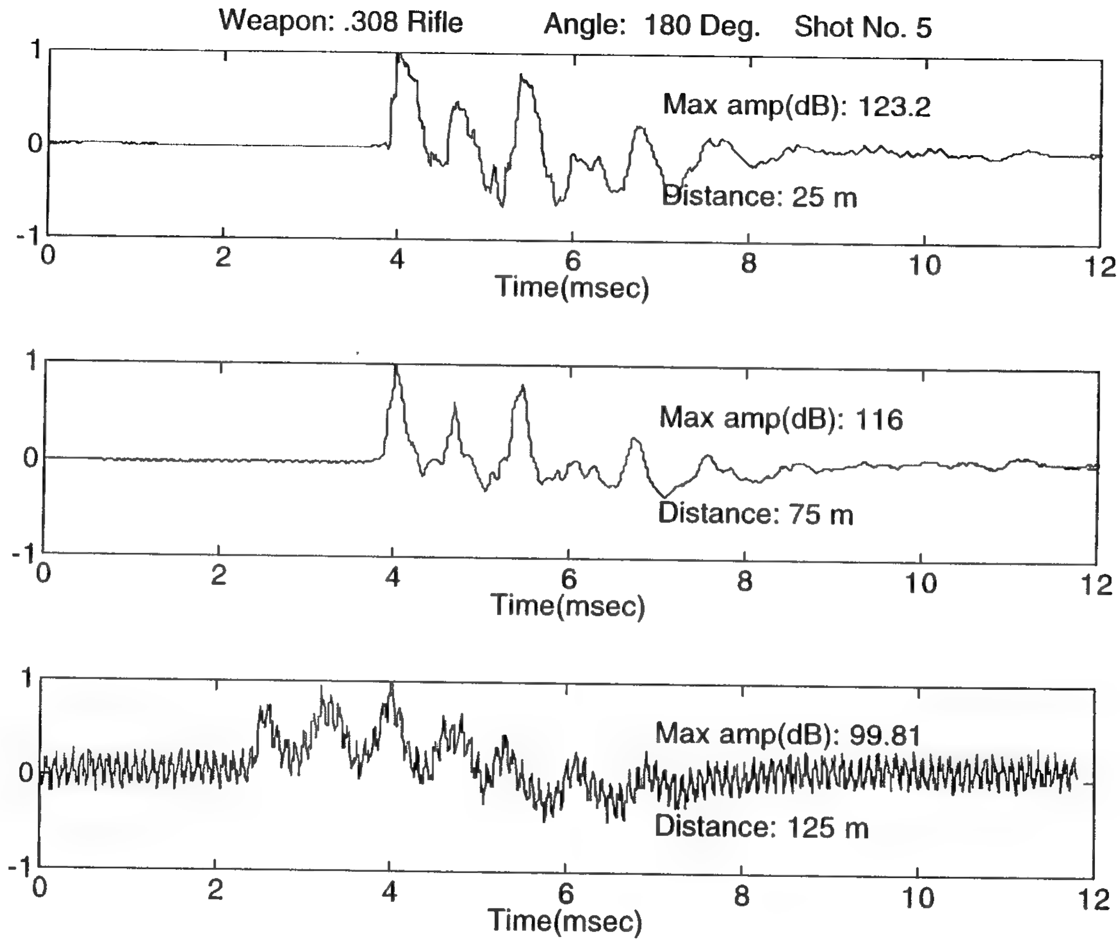
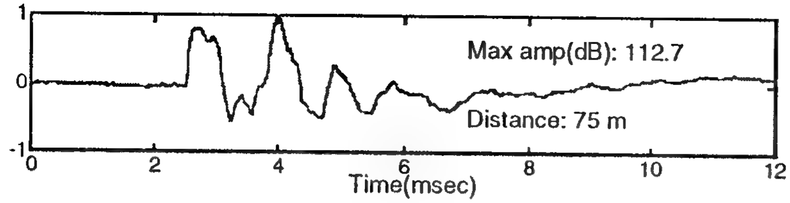
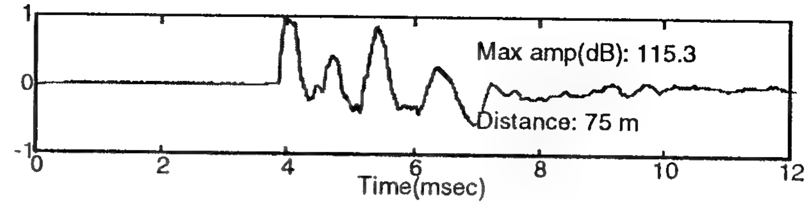


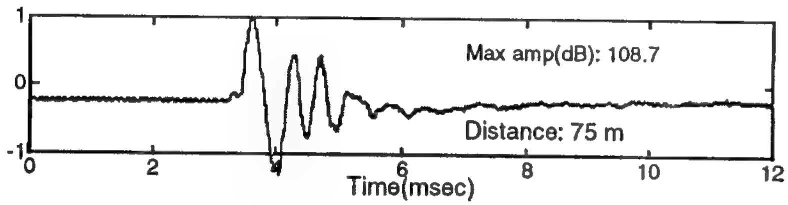
Figure 3.1.-5: Waveforms vs. Distance 180°



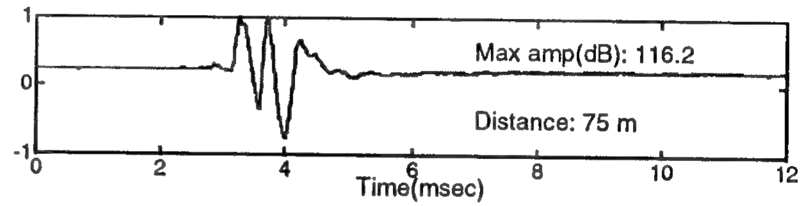
12 Gauge Shotgun (slug)



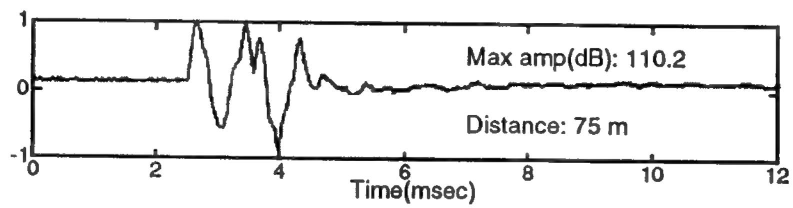
.308 Rifle



9mm Glock



.45 ACP



.38 Special

Figure 3.1-6: Possible Weapon Classification Rear Acoustic Detection

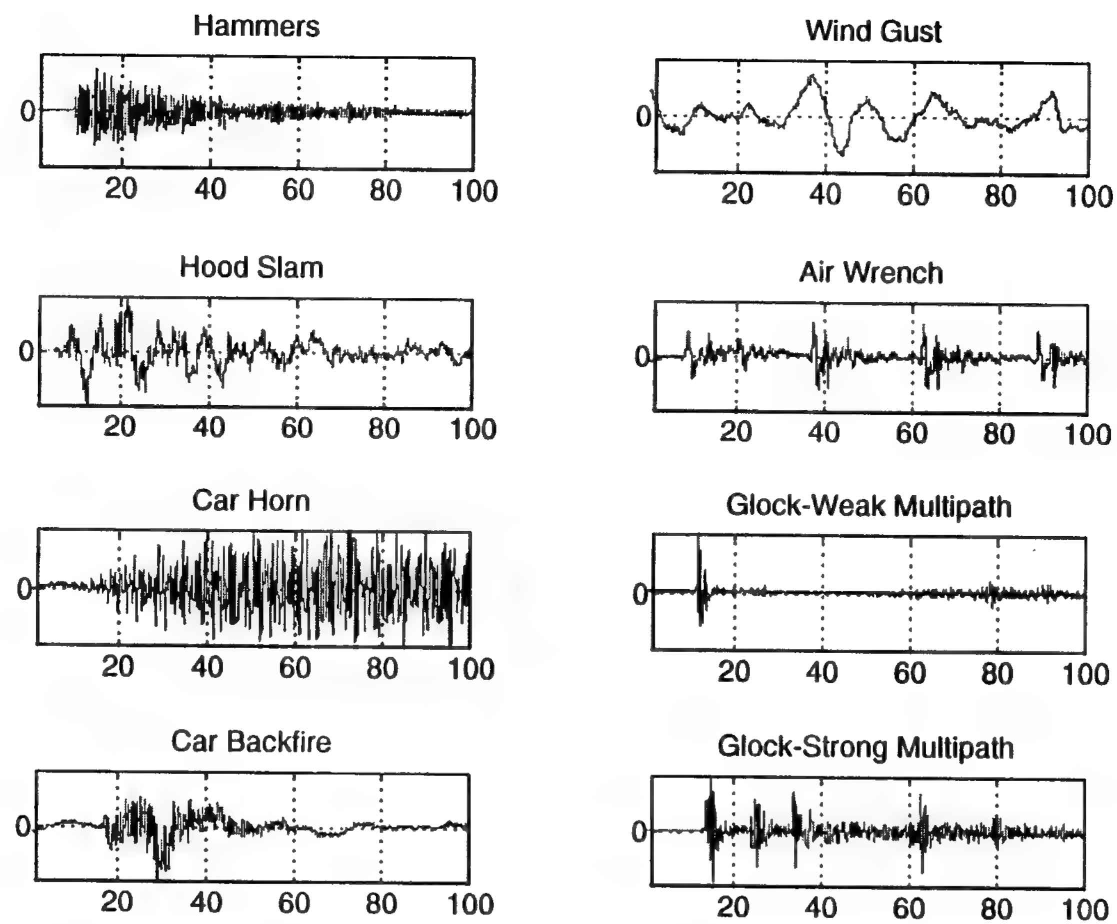


Figure 3.1-7: Gunshot and Background Noise Waveforms

- Gunshots Fired Within 400’ Of The Microphone:
  - Rapid On-Set Of Pulse Above Background (> 12dB Increase In < 1 msec)
  - Pulse Absolute Amplitude > 90dB
  - Pulse Duration: 1.5 - 8msec

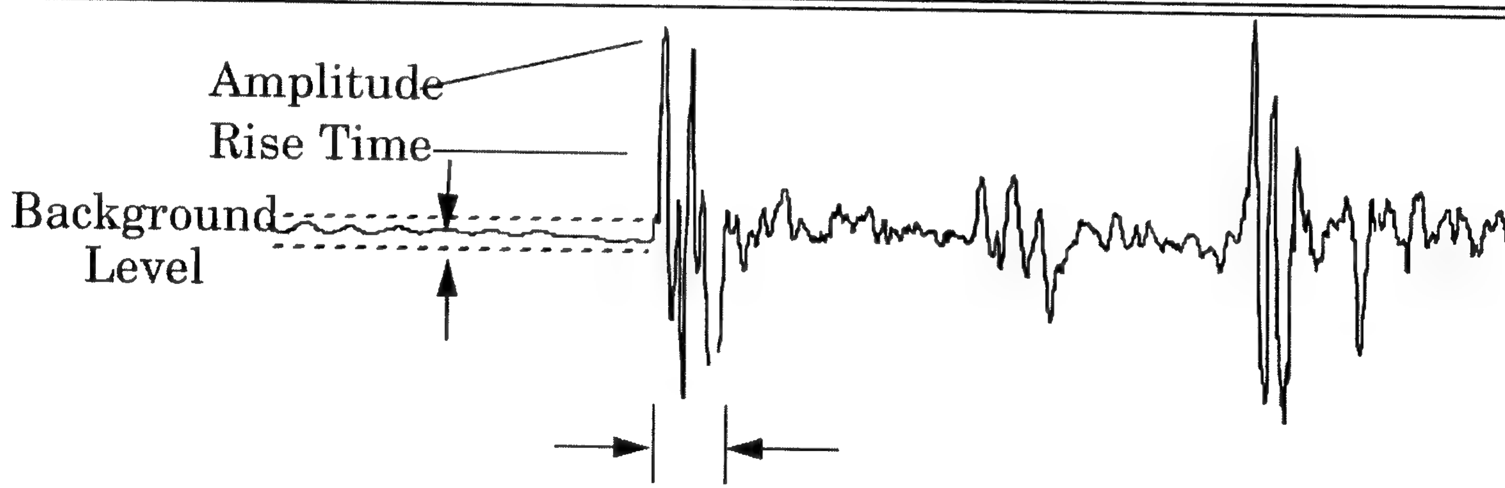
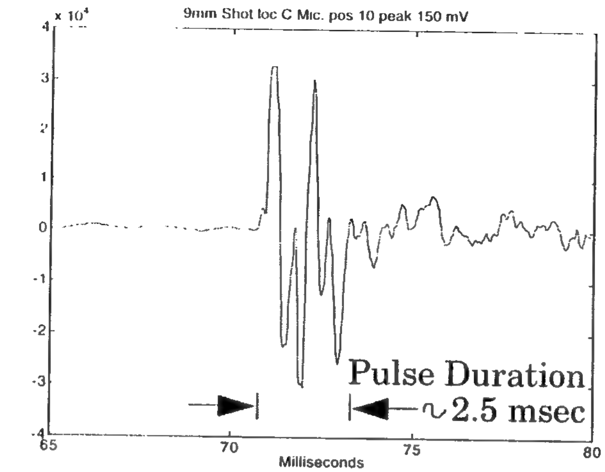
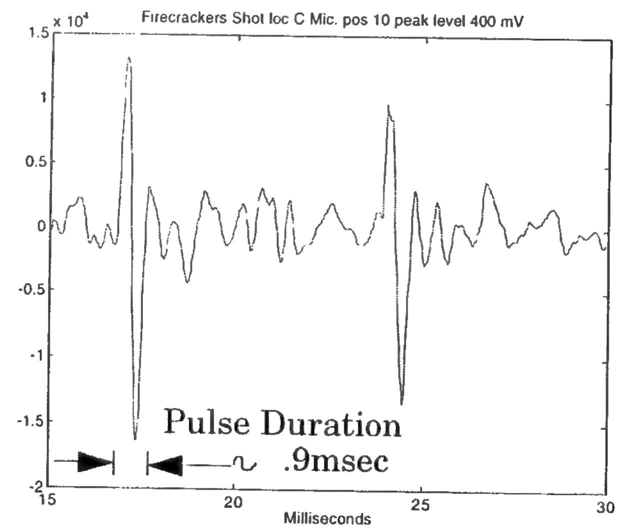


Figure 3.1-8: Current Gunshot Identification Characteristics

(Waveforms Detected At 300’ From Sources In Building Complex)



9mm Glock



2 - 1” Firecracker

Figure 3.1-9: 1” Firecracker vs. 9mm Glock In Reverberant Environment

it and later arrivals. Both situations preserve this pulse duration information. Figure 3.2-1 gives examples of gunshot multipath waveforms and indicates the presence of the short duration first arrival pulse. Figures 3.2-2 and 3.2-3 show examples of the gunshot waveform observed at three different locations along a 350' indirect propagation path through the Marine Combat Base building complex. The short pulse duration of the first arrival has been preserved even with scattering and multipath arrivals. For more difficult situations in which a building near the gunshot completely blocks the direct path, two or more multipaths may overlap and obscure the first arrival short pulse duration. In these cases it may be possible to identify gunshots by detecting the gaps between multipath arrivals or detecting a delayed muzzle blast or N-wave arrival. This is illustrated in Figure 3.2-4. With the reasonable placement of pole units in urban environments it is expected such difficult cases to be relatively rare. However, plans are being formulated to test algorithms that key on the gap and late pulse arrivals if they are present as well as spectral and other characteristics.

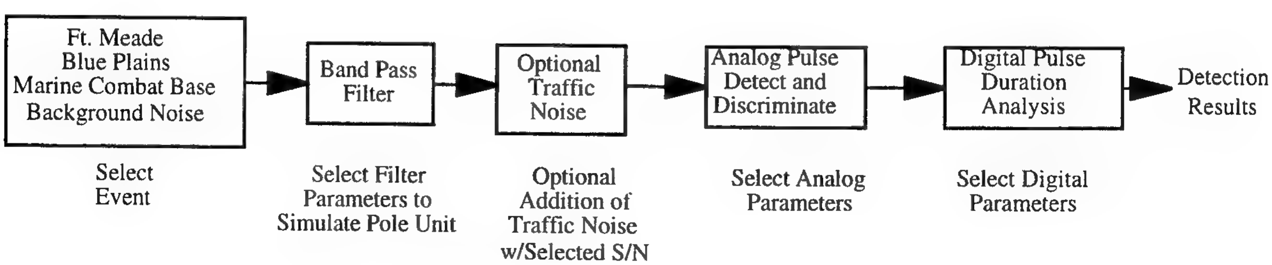
3.3 Gunshot Detection and Classification Procedure

The gunshot detection and classification method currently being investigated for SECURES™ is based on the three characteristics of the acoustic waveform described earlier: pulse rise time (<1msec), amplitude (>90dB), and pulse duration (1.5 to 8msec) for the full range of weapons tested to a range of 125 meters. This method is planned to be implemented using analog pulse detection circuitry for detection of explosive events meeting the rise time and amplitude criteria, followed by digital processing to measure the risetime and classify the explosive event as a gunshot, other explosive event, or as of no interest. This approach is illustrated in Figure 3.3-1. Details of the analog pulse detector and risetime analyzer and the digital pulse duration and multipath discrimination were developed under IR&D funding, and are considered company proprietary. Additional discrimination analysis can be performed at the host computer, if necessary, which could take advantage of information received from multiple pole units to improve localization or provide a cross check on the gunshot identification.

3.4 Detection and Classification Performance

3.4.1 Test Procedure Outline

The combined analog and digital gunshot detection and classification algorithm has been evaluated using a computer program developed to emulate the complete acoustic waveform analysis process intended for the pole unit. This emulation allows one to vary the analog and digital analysis parameters and evaluate gunshot detectability and false alarm rates on the acquired database of gunshots and background noises. The flow chart below indicates the key functions of this software.



First an event waveform is selected from either the Ft. Meade,the Blue Plains, the Marine Combat Base, or the background noise database. The waveform is then filtered to simulate the selected bandwidth of the microphone and pole unit electronics. Next, there is the option to simulate a

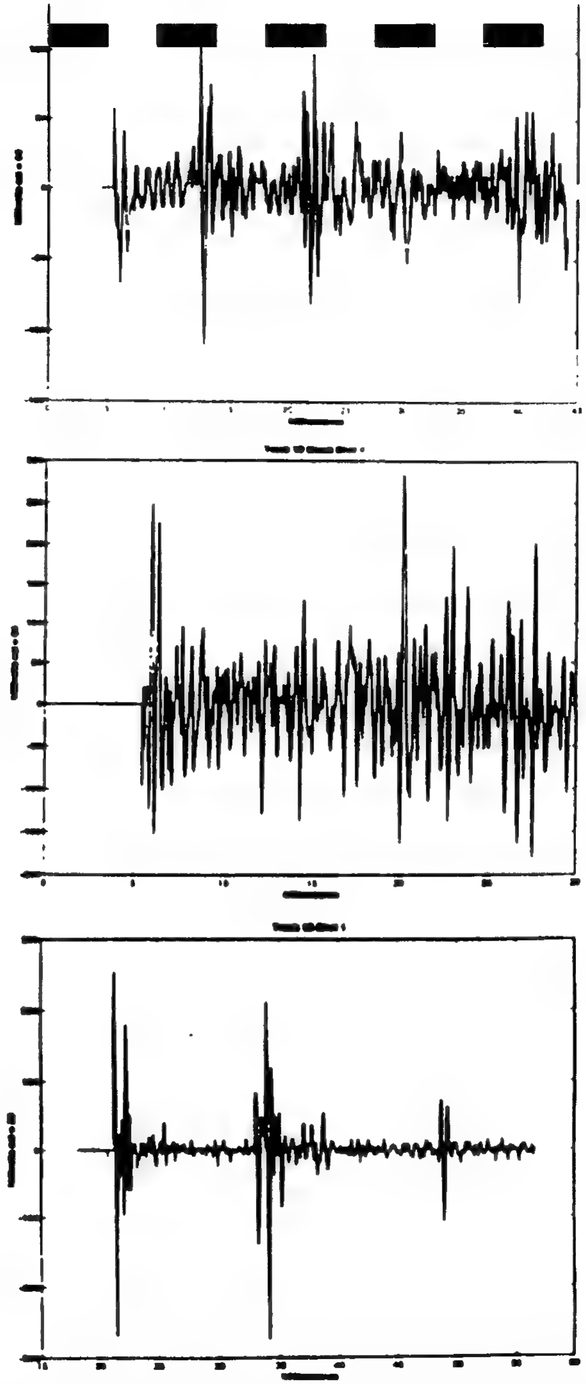


Figure 3.2-1: Sample Gunshot Multipath Waveforms

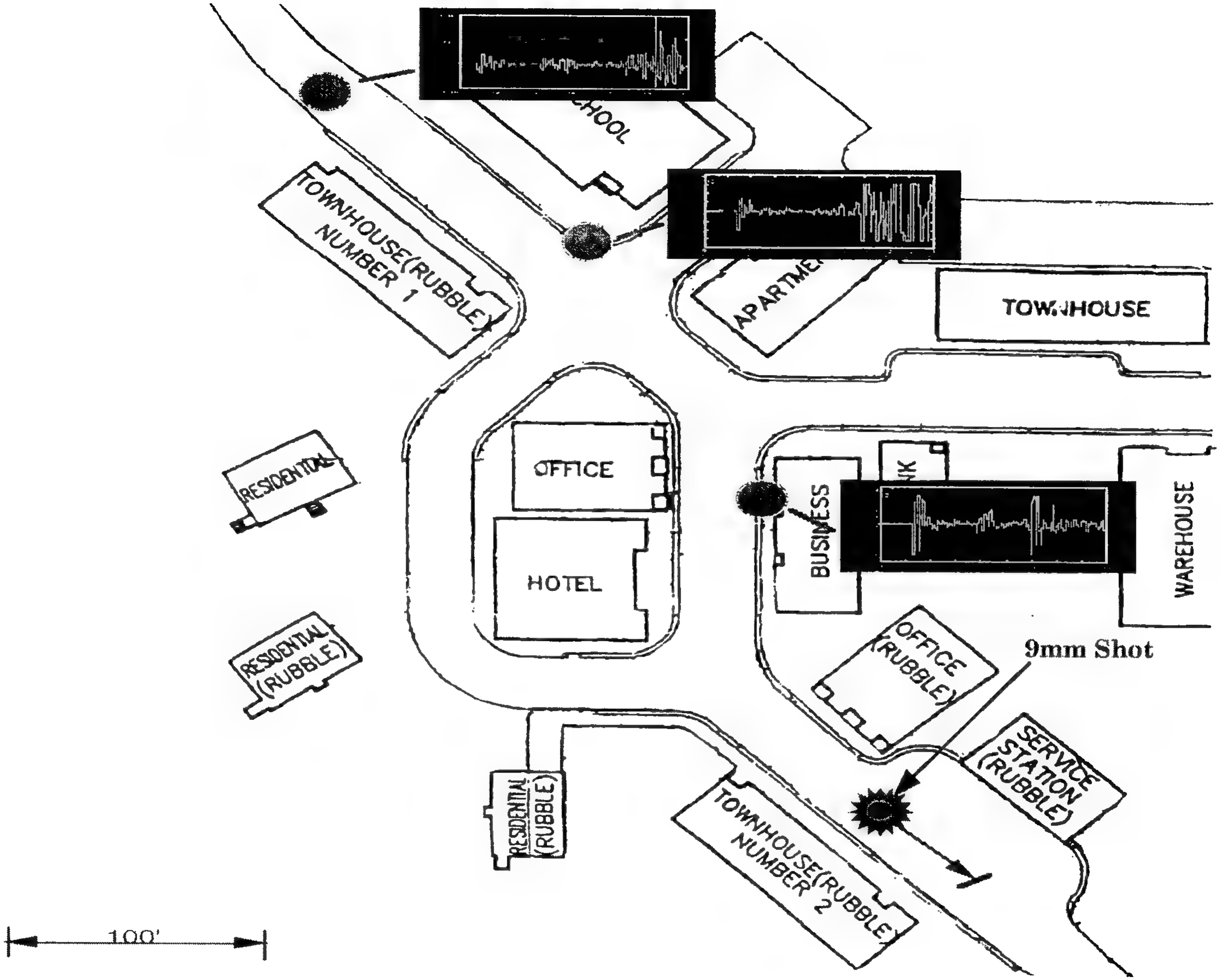


Figure 3.2-2: Gunshot Reverberation In Building Complex

(9mm At Location C In Marine Base Complex)

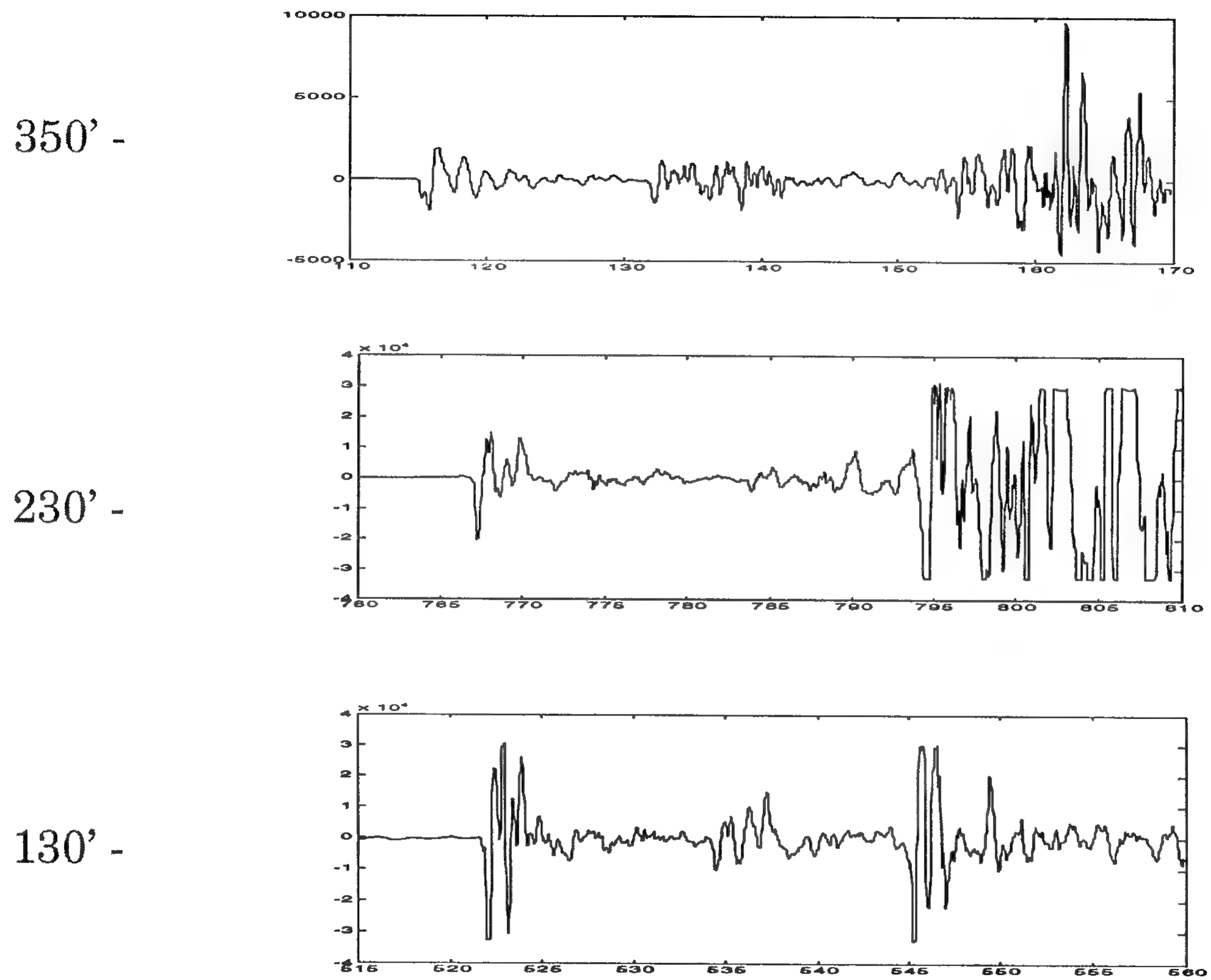


Figure 3.2-3: Gunshot Reverberation In Building Complex (Blow Up Of Waveforms Shown In Figure 3.1-11)

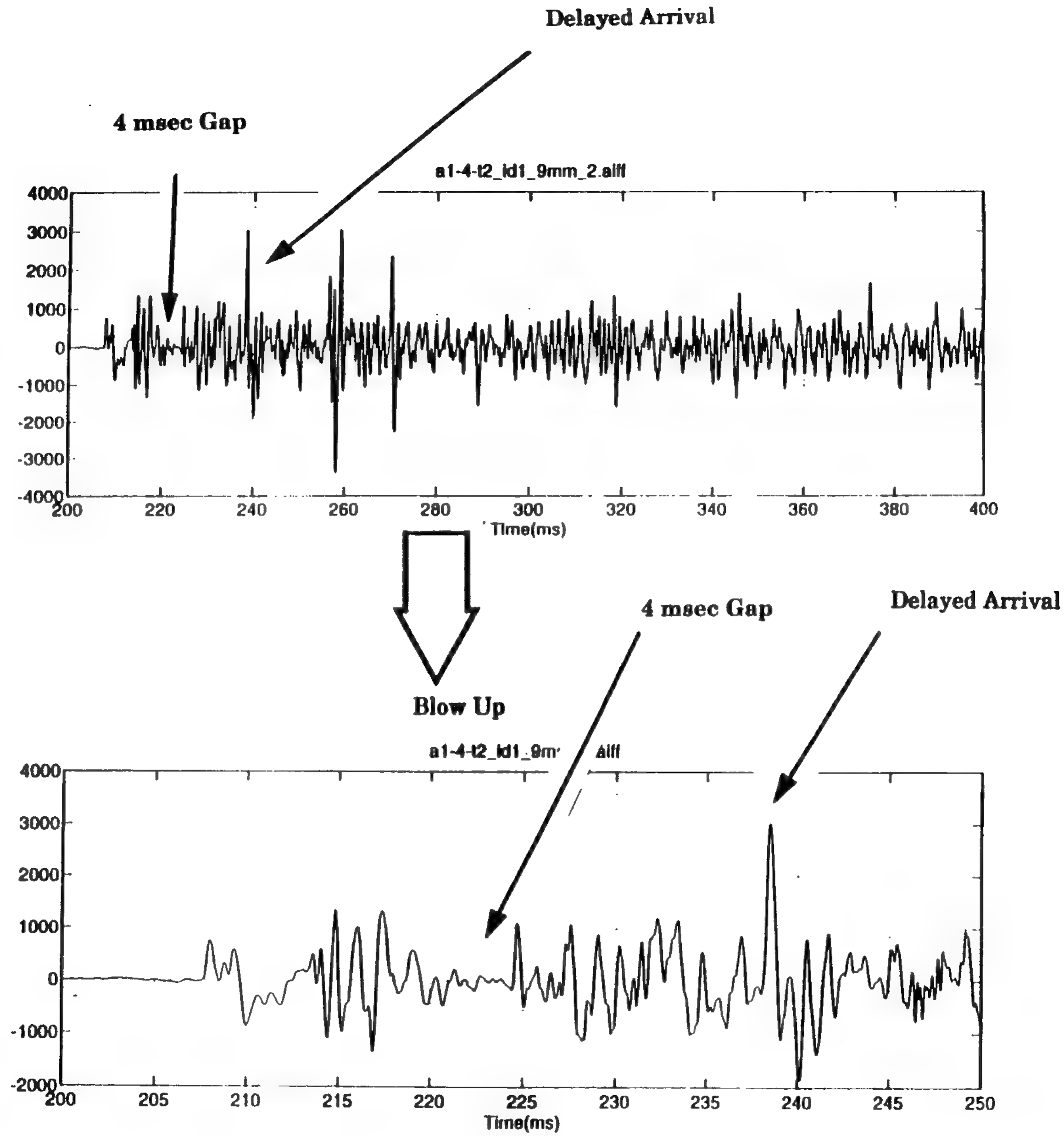


Figure 3.2-4: Gunshot Identification Through Delayed Pulse And Gap Detection

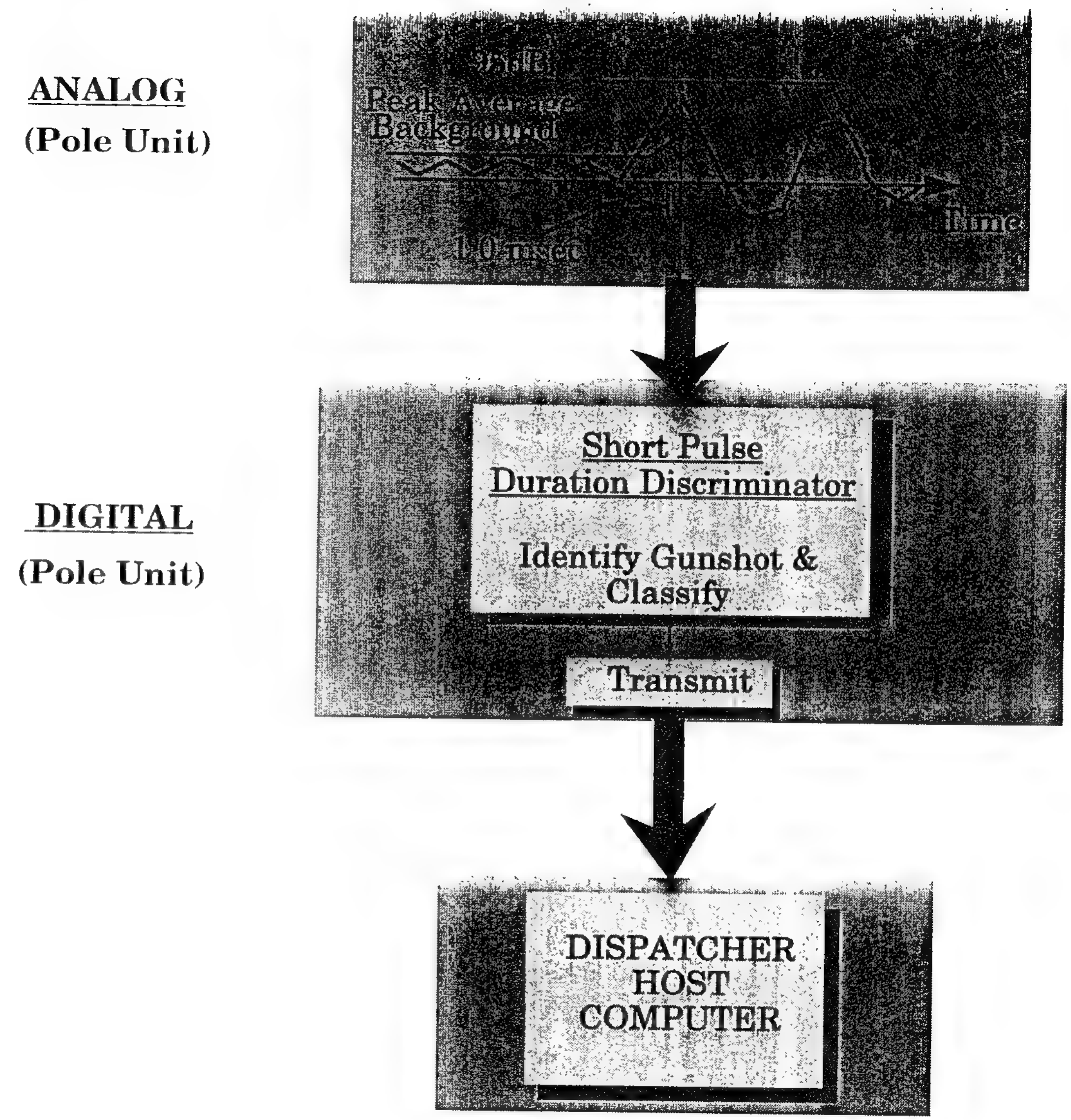


Figure 3.3-1: Current Method ForGunshot Detection & Classification

higher background noise situation than was present at the recording site by adding recorded traffic noise at a selected signal to noise ratio.

An analog pulse detection emulation is then performed using a selectable set of test parameters including rise time, decay time, and absolute sound level. If the pulse detection triggers, the event is classified as a possible explosive, and passed to the digital discrimination process. The digital process separates the detected events into three classes - gunshots, other explosive events such as firecrackers and blanks, and non-explosive events of no interest. Only the gunshot class is considered a detection. Parameters can be selected for this analysis to vary the features of the digital process. The software then cycles through the entire database and generates a summary report on each event analyzed. This report identifies which events triggered the analog pulse detector, and which of these subsequently passes the pulse duration test. The summary report then allows us to determine, for each set of analog and digital processing parameters, the percentage of the gunshot events detected and the percentage of background noise events that false-alarmed.

3.4.2 Test Data Base

The database used for the current evaluation is described in the chart on the following page. It consists of an assortment of weapons, ranges and directions of fire relative to the microphone, and was representative of data recorded at three test locations. It also includes 1" firecrackers, blank .22 firings, and a variety of background noises.

In considering what background noises present the greatest false alarm problem to SECURES™, one must consider both the probability of the noise causing a false alarm and the frequency of encountering the noise. A nail gun, backfire, or firecracker may appear on the surface to present the greatest problem because their sound closely resembles that of a gun, but these are fairly infrequent events. This must be compared with the risk of persistent traffic noise, wind noise or other noises (although not sounding very much like a gun) having a chance variation in their waveform that could resemble that of a gunshot for a brief period of time such as ten milliseconds. This short portion of the waveform would not be noticed by the ear to sound like a gunshot.

Another way of looking at the false alarm situation is to consider that the pole unit is making decisions on the order of 100 times per second on whether or not a gunshot is present. Thus, even though the acoustic waveforms of traffic do not sound like gunshots, the traffic noise gets hundreds of thousands of chances each hour to generate false alarms. Thus it is important to verify through tests that the system has extremely low false alarm rates for the frequently-encountered waveforms of sounds such as wind and traffic. Tests performed earlier in the development were very encouraging in demonstrating that the breadboard analog pulse detection circuit had no false alarms when subjected to twenty minutes of recorded loud traffic, wind gusts, horns, clanks and other common street noises. The following lists the type of acoustic events in this database and their number.

SITE	TYPE OF EVENT	# OF EVENTS
Marine Combat Base	M-16 9mm .38 Shotgun 1" Firecracker	9 11 12 6 10 **50**
Blue Plains	9mm	**21**
Ft. Meade	M-16 .45 .38 9mm Shotgun .22 blank 1" Firecracker	8 7 7 8 5 8 7 **50**
Environmental	Wind Traffic & Wind & Horn Windgusts Hammer Blows Airwrench Hood Slam Door Slam Car Backfire Horn	4 periods 1 period 1 period 5 1 burst 1 1 1 1 **16**

Total Gunshots	96
Total .22 Blanks	8
Total 1" Firecrackers	17
Total Noise Records	16
TOTAL # OF EVENTS	**137**

3.4.3 Detection and Classification Results

The table below reports the results for a fixed set of detection parameters . The results labeled First Pass show the separation those events which passed the analog detection criteria into explosive and non-explosive categories. This process classified 91 of the 96 gunshots as explosive events with no false alarms from the non-explosive events. The results labeled Second Pass show the attempt to eliminate 1" firecrackers and .22 blanks from the explosive events. These results show than one .22 blank was incorrectly classified as a gunshot and one gunshot was incorrectly classified as a 1" firecracker or a .22 blank. The overall resulting detection performance was identification of 90 of the possible 96 gunshots with one false alarm.

The six gunshots not detected were: (1) a .38 pistol fired from position A1 and recorded at position P4 (see Site A- Figure 2.4-1) (This was a very difficult propagation path); (2) 2 shots from a .38 pistol fired from position B7 and recorded at position P5, which was partially blocked by a building (see Site B- Figure 2.4-2); (3) 2 shots from a M-16 rifle fired from positions A3 and A4 and recorded at position P3 (see Site A- Figure 2.4-1); (4) .38 pistol fired at Ft. Meade in the direction of the microphone and which had an unusually short pulse; and (5) a .22 blank fired at Ft. Meade which had a longer than normal pulse for a blank, triggering the one false alarm.

To give an idea of how this detection performance changes with the selection of detection parameters, a second set of parameters was selected and the test repeated. The false alarm rate was reduced to zero, at the cost of a reduction in detections to 86 out of 96. These results are very encouraging since the shots missed were from difficult locations that in the city would likely be detected by better positioned sensors. However, this data set is limited and high noise background noise performance has not yet been examined (although it is expected the gunshot background noise levels present in this data set to be at the minimum representative of those during evening hours).

	gunshots meeting explosive event criteria	non-explosive events meeting explosive criteria
First Pass	91 / 96	0 / 16

	gunshots meeting short duration explosive event criteria	failing short duration explosive event criteria
Second Pass	1 / 91	1 / 25

	gunshots detected	false alarms
Overall Detection Results	90 / 96	1 / 41

More detail on the above detection performance can be seen in Appendices A and B. These figures list each event analyzed for the above results, and are labeled as "gun", "blank", "firecracker", or "noise" on the right. Appendix A shows the first pass results, and Appendix B shows the second pass results.

4.0 System Hardware Development

From the depiction of the SECURES™ system concept in Figure 1.0-1 and 1.0-2, it is clear that the pole units are the heart of the system and present the biggest challenge in the hardware development of the system. (The host computer and the possibly RF relay stations would be the other main hardware components of the system.) The design goals for the pole unit are the following:

- Reliable identification of gunshots
- Very low false alarm rates
- Low cost, easy to install
- Long life operation in outdoor environments

The first two of these goals are algorithm-dependent, while the last two depend on careful design of the pole unit. The key design feature which leads to long life with low maintenance is the use of staged powering of the electronics, an approach in which only the ultra-low power analog circuitry is constantly powered. The digital and communications components are power up only when required, leading to a very low duty cycle. The design strategies used to guide the development of the pole unit are illustrated in Figure 4.0-1

The decision to utilize staged powering of the electronics resulted from an investigation into the primary options for powering pole units over extended periods. These options include line power, solar power and battery power. Availability and requirements for hooking up to line power at desired locations for pole units and are considered to be too restrictive for the SECURES™ concept. Use of solar power has been investigated and is workable; however the unit would be more complex, also require batteries for the surge power required by the transmitter, and present some limitations in the placement of units. Operating from relatively small batteries for extended periods is the most desirable solution, but requires an ultra-low power electronics design which can meet the frequency response, dynamic range and temperature range requirements for this application.

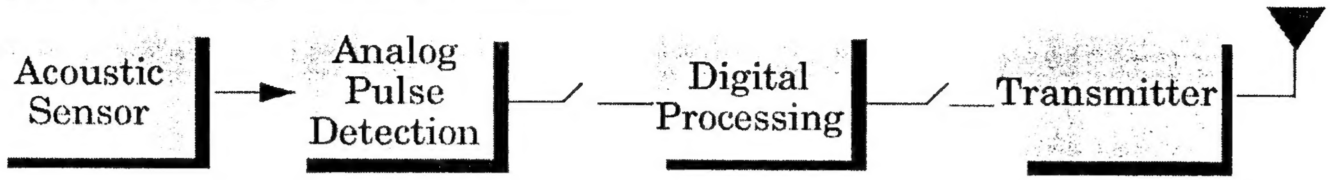
Based on investigation into electronic design options, the battery option appears to be possible through off-the-shelf components together with innovative circuit design and staged powering of the electronics. In the staged powering approach only the analog pulse detection circuitry would be operating continuously; however some additional power would be required to keep the digital processing circuitry in standby. The digital circuitry would only be fully powered for a short time after the analog circuit triggers. If the digital processing (expected duration of less than .5 seconds) algorithm decides that the event is a gunshot, the transmitter is then powered up to transmit its message. This approach greatly reduces power requirements.

5.0 Summary

A study was performed to determine the feasibility of developing a reliable and practical system for instant localization of gunshots in urban environments, based on Alliant's SECURES™ system concept. This effort involved:

- Investigation into methods for acoustic identification of gunshots, including:
  - acquisition of a large database of gunshot acoustic data in open field and building environments,
  - acquisition of environmental background noise data,
  - analysis of these data to determine characteristics of gunshot waveforms that discriminate them from background noise, and

- Staged Powering Of Electronics



	Long Life	Cost	Enhance Gunshot Identification
Ultra-Low Power Analog Pulse Detection Circuitry (100micro-amps)	✓		
Two D Cell Lithium Batteries	✓		
Commercially Available Dynamic Acoustic Sensor	✓	✓	✓
14 bit A/D Design Incorporating Three 8 Bit A/D's For Low Standby Power, Quick Power Up & Low Cost	✓	✓	✓
DSP & PIC Processor Selected For Flexability In Processing At Low Cost		✓	✓
Low Cost, High Data Rate RF Transmitter		✓	✓

Figure 4.0-1: Design Strategy

- development of the performance of the identification methods using recorded gunshot and noise data.

- Investigation into SECURES™ system hardware design, including:
  - design, computer emulation, and breadboard testing of the pole unit's ultra-low power analog pulse detection circuitry,
  - preliminary design of the pole unit's quick start, low standby power A/D, and its digital processing electronics,
  - selection of key pole unit electronic components, including acoustic sensor, battery power supply, and DSP,
  - development of pole unit enclosure and mounting hardware concept, and
  - preliminary trade-off analysis of data communication options.

Key findings based on these investigations were:

- The current version of the gunshot identification method, based only on pulse rise time, duration, and amplitude performed very well in identifying gunshots from a database of 137 acoustic events (including gunshots fired within building complexes). This method was successful at discriminating small 1" firecrackers from gunshots but is generally not capable of discriminating gunshots from much larger explosive devices.

- Pole unit electronic hardware capable of implementing the current gunshot identification method operate from small batteries, survive outdoors for extended periods, and able to be produced economically using off-the-shelf components appears to be feasible.
- A commercially available CDPD transceiver appears to be the most attractive means of communicating data from the pole unit to the police dispatcher, with the provision that this electronics can be obtained at an acceptable price.

The status of the hardware development is:

- The hardware/electronics concept has been developed in-house.

- The design, breadboard and testing of the analog pulse detection circuitry is on-going.

- The ultra-low power analog and digital design options for the pole unit is being investigated.

- The preliminary design of the pole unit analog and digital electronics is completed.

- The design, breadboard and testing of teh ultra-low power analog pulse detection circuitry has been completed.

- The design for the low standy waveform A/D capture electronics has been completed.

- The packaging and mounting concept for the pole unit has been developed.

Key areas that need further investigation are:

- The gunshot identification method needs to be tested on a larger database of gunshots, longer periods of city background noise, and with higher background noise levels.

- The performance of the pole unit's ultra-low power electronics needs to be investigated over a wide temperature range and in high electromagnetic interference environments.

- High volume OEM pricing of commercial CDPD transceiver electronics needs to be investigated to determine the viablity of this communications approach.

- Investigation into enhancements to the current gunshot identification method based on additional acoustic discriminants needs to be pursued.

- An evaluation of whether an all-analog gunshot identification design would be sufficient, thereby eliminating the A/D and DSP electronics and greatly simplifying the pole unit hardware.

- A pilot program consisting of 30 - 50 prototype pole units installed in a typical high crime area needs to be conducted. This will allow evaluation of the current SECURES™ system hardware and function design concept in an urban environment for an extended period of time (e.g., 3 months).